

**Before the
Federal Communications Commission
Washington, D.C. 20554**

In the matter of)	
)	
Establishment of an Interference Temperature)	
Metric to Quantify and Manage Interference and)	ET Docket No. 03-237
to Expand Available Unlicensed Operation in)	
Certain Fixed, Mobile and Satellite Frequency)	
Bands)	

COMMENTS OF SIDDHARTHA RAJA

This comment suggests and analyses the possibility that electromagnetic spectrum owners or users manage radio interference independent of the Federal Communications Commission (FCC). The FCC proposes to manage interference through a regulator-defined metric called interference temperature. The paper first assesses the FCC proposal, and then suggests that possibilities exist wherein interference can be managed individually by processes other than what the FCC proposed, independent of direct regulatory control. Instead it is possible that individual agents can minimize interference according to their own objectives and constraints including criteria set by the regulator.

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I. INTRODUCTION

One intention of the regulation of electromagnetic radio spectrum (spectrum) and wireless devices by the Radio Acts of 1912 and 1927 was to minimize interference between different services and devices (Benkler, 1997, p. 298-314; Coase, 1959; Faulhaber & Faber, 2003; Hazlett, 1998, p. 532; Powell, 2003). At present, services and systems using Wireless Fidelity (WiFi), Code Division Multiple Access (CDMA) techniques, and agile radios utilize the electromagnetic radio spectrum more efficiently and more intelligently. Interference is not the problem that it was before, due to advances in communications systems and the development of discriminating receivers. While it no longer remains a sufficient reason for the regulation of spectrum, interest in interference protection and management is not anachronistic. It is relevant because interference leads to service quality degradation, which harms spectrum-based services and users. Thus, there is a need even today to minimize and prevent radio frequency interference. The major change is that regulatory organizations today have realized that interference is not a transmitter-side or wireless-media problem, but of the receiver - it has been recast as a problem of poor discrimination at the receiver rather than of the spectrum or services itself. Regulatory systems have thus to revise their spectrum allocation, management, and regulation policies to keep up with changes in technology and understanding to deal with interference.

II. THE FCC'S RESPONSE: MANAGEMENT USING INTERFERENCE TEMPERATURE

The FCC began to rework its own spectrum policy and FCC Chairman Michael Powell instituted the Spectrum Policy Task Force (SPTF) on June 6, 2002 with the aim defined as “identifying and evaluating changes in spectrum policy that will increase the public benefits derived from the use of radio spectrum” (FCC, 2002a). On November 7, 2002 the SPTF presented its findings and recommendations to the FCC at an open meeting (FCC, 2002b). The Spectrum Policy Task Force Report (SPTF Report) included many findings and recommendations aimed at better interference management for spectrum users (FCC, 2002c, p. 25-34) as interference, due to its ability to hamper communications using radio frequency devices is harmful to the public good (FCC, 2002c, p. 1). By using a metric called “interference temperature”, the FCC wishes to create new quantitative standards to measure and manage interference (FCC, 2002c, p. 27).

The concept of interference temperature is first introduced in the Report of the Interference Protection Working Group (IPWG) to the SPTF (FCC, 2002d, p. 11-15). In the notes to the IPWG report (FCC, 2002d, p. 13), it is explained that “interference temperature can be calculated as the power received by an antenna (watts) divided by the associated RF bandwidth (hertz) and a term known as Boltzman’s Constant (equal to $1.3807 \text{ wattsec/}^{\circ}\text{Kelvin}^1$)”. The FCC explains that interference temperature is a measure of “the RF power available at the receiving antenna per unit bandwidth” (FCC, 2002c, p. 27). Further explanation of the concept is provided by the IPWG, which explains, “interference temperature. . . is synonymous with the concept of antenna temperature.”² (FCC, 2002d, p. 13)

By managing interference using a dynamic metric, the FCC hopes to provide a system in which primary users of the spectrum are assured of a minimum quality of service, but at the same time increases the access and flexibility afforded to the secondary users of spectrum (FCC, 2002d, p. 18-19).

III. ASSESSMENT OF THE METRIC

In public comments to the FCC, the interference temperature concept has been criticized as technically unrealistic³. There is no reason to believe that the FCC should or could organize the spectrum continuously and effectively this way. As AT&T Wireless (2003) states in its comment to the FCC:

The interference temperature concept places complete faith in the Commission's ability to set permissible levels of increased interference for all interference environments...

There is no basis to conclude that this approach is practical, technically feasible in any meaningful timeframe, or enforceable. (p. 12)

The FCC also does not completely let go of its control over spectrum. The main source of control in the interference temperature model is the FCC plan to "undertake a systematic study of the RF noise floor" (FCC, 2002c, p. 5), and to set "an interference temperature for a particular band" (FCC, 2002c, p. 33). The FCC maintains a standard defined over different regions of spectrum, and used by all devices to control interference. Thus, the FCC seeks to provide more flexibility in the use of spectrum, but does not completely relinquish control over the limits to flexibility.

Indeed, the interference temperature metric is a turning point in the method of regulation. The FCC could have opted to continue with static or obsolete methods, but has made an attempt to define a new regulatory paradigm that is based on what seems to be a dynamic and technologically responsive method of managing interference. Its inclusion is a positive step, proving that the FCC is interested in creating new regulatory mechanisms. This is an important point to remember in any future debate.

Any debate about interference management must go beyond mere technical deliberation. Spectrum is an important natural resource, and any regulation generated at present is likely to stay in effect for an extended period of time. It is important to ask if new rules are necessary, especially at a time when archaic regulatory methods are being challenged by new technology and new models of allocation, regulation, and governance. If we do not, we risk outcomes where possibly millions of users and devices are bound by rules that prevent technological progress, promote inefficiencies, or result in sub-optimal outcomes. Similarly any interference management technique should be evaluated because regulatory inertia and vested interests might cause the propagation of unneeded restrictions – carrying to the future some past justification for spectrum regulation.

Ultimately, as Mueller argues about the Internet and the DNS (2002, p.8), this issue also forces us to ask where technical management ends and regulatory control begins.

This paper argues that interference need not be managed on some universal level. While it is beneficial to have some minimum criteria that devices and services should follow to avoid misuse of spectrum, it is not required that the details of managing interference be decided at a regulatory level. To argue this, we consider different cases of the spectrum allocation models used.

IV. INTERFERENCE MANAGEMENT AND SPECTRUM ALLOCATION MODELS

A major factor in future spectrum policy is the choice of models of spectrum allocation. We consider the models of allocation proposed by the SPTF (FCC, 2002c, p. 35) are command-and-control, spectrum-as-property, and a spectrum commons. In the property and commons regimes, spectrum users and owners will have the right to use spectrum in flexible and reconfigurable ways. Imposing a regulator created, universal interference management technique on the dynamic, user-defined spectrum of the future is incongruent with the almost certain allocation of spectrum to individual agents – users of commons, or owners of property. The actions and choices of the owner or user of spectrum would lead to agent-level interference management, as long as minimum quality-of-service or access obligations are fulfilled.

This paper proposes that interference management be reevaluated considering spectrum primaries – the users and owners of spectrum. They could manage and control harm due to interference independent of the FCC. Thus, an alternative system to manage interference might exist. To prove that such a system would actually work, we consider what might happen in each of the likely spectrum allocation regimes and specifically recognize how interference might be managed in each case.

The three models for spectrum allocation considered by the SPTF are the command and control, property-rights, and a commons models. A complete discussion of the models of allocation is out of the scope of this paper, and the question of which method of spectrum allocation is best to use is an entirely different and engaging debate in itself. A complete discussion of these models can be found in Benkler (1997), Benkler (2002), Coase (1959), and Faulhaber and Farber (2003).

In a command-and-control system, the level of protection is, has traditionally been, and would continue to be, the highest (Powell, 2003).

In a spectrum commons regime, levels of interference will depend on device usage, density, and capability. It would be rational behavior for commons spectrum users to avoid interference in order to have the highest quality of communications. Even presently available devices such as agile radios can use frequency hopping to find the least crowded frequencies to transmit over. Thus, if certain parts of the spectrum have a greater probability of interference, users would move from those regions of the spectrum to less crowded ones, or use different encoding and decoding mechanisms to improve discrimination. This will lead to equilibrium where the level of interference will be the least for a given number of users.

In a property-rights regime, it can be expected that strict definitions may exist over the level of interference that can be suffered by the primary user or owner of the spectrum (primary), so as to protect the basic communications capability of the primary. Interference protection could provide minimum levels of interference that primaries should be ready to suffer, as necessary to allow low-power FM radio operation, for example. Such devices could function according to the FCC Part 15 Rules, for example, where unlicensed wireless devices are allowed to emit radio frequency transmissions as long as certain rules are followed⁴. However the primary might allow easements, and hence allow for greater levels of interference. This possibility is discussed in Faulhaber and Farber (2003, p. 14) and a possible arrangement arising from this is presented in the following section.

The SPTF recommends that the FCC should not adopt a one-size-fits-all policy for spectrum (FCC, 2002c, p.3) and use all three models for different services and regions of the

spectrum. With this in mind, we now analyze the possible minimization of interference, responding to the different characteristics of each of the models.

The command-and-control model will be most likely applied to regions of the spectrum used by services that must be protected at all times, such as navigational aids or emergency service bands. In this case, the regulator and possibly primary must and will enforce strict interference protection rules, and there is no need for any management of interference, as any interference might be deemed illegal.

Spectrum as Commons

The commons model might not require interference management. The reasons for this are as follows:

1. FCC Rules, such as used in Part 15, could control transmission power limits for devices using the commons. This will reduce interference due to receiver capture⁵.
2. The commons operates on etiquette expectations. Enforcement by the FCC can ensure that users follow these “rules of politeness”, and given the collective action characteristic of the commons, it is again reasonable to expect user reports of misuse of the commons and demands for enforcement.
3. Receiver design improvements will improve discrimination capabilities over time, reducing the probability of adjacent channel interference, or bleed over. This follows from the rational behavior of commons users to protect them from interference.

Following these characteristics of the commons, it is expected that commons users would seek to minimize interference in their communications and to find the lowest level of

interference that is compatible with their individual objectives. While the individually determined solution might be less optimal than a system-optimized solution, we can still expect a majority of commons users to bear such results. There is evidence from similar situations where overall losses in utility are possibly acceptable and not crippling to the functioning of the system (Johari & Tsitsiklis, 2004). This is also creates incentives for further innovation into better receiver and transmitter design or new standards and protocols of communication, forwarding the aim of the commons as a site of innovation. It would then unnecessary to impose complex interference management techniques for this model.

Spectrum as Property

In the spectrum-as-property regime easements might exist depending on the choices the primary makes (Faulhaber & Faber, 2003). If easements exist, it might be required that interference measurement and control methods be used to maintain minimum quality of service. If no easements were allowed by the primary, control of interference within the owned spectrum could be similar to the command-and-control style. The next section fully explores interference management in the property-rights with easements context.

V. THE SPECTRUM-AS-PROPERTY WITH EASEMENTS CASE

In a spectrum band following the property-rights with easements regime, there are two parties involved. One is the interferee, the party bearing the interference, who will usually be the primary. The other is the interferer, the party who uses the easements, who we will refer to as the secondary. As Benkler (2002, p. 31) explains, the social cost of wireless communications includes “aggregating the equipment and servicing costs involved, the displacement of communications not cleared, and the institutional and organizational overhead in the form of transaction costs and administrative costs”. This indicates that there exist externalities in the use of wireless communications – especially if the communication prevents the use of the medium by others – the state typical of interfered-with communication – that Benkler refers to as displacement costs. Given that a cost exists due to displacement of one party’s communications for another, two possibilities arise. The first is that the cost can be minimized by a two-way interaction between the interferer and interferee – the creator and bearer of the costs of displacement due to interference. The second possibility is the creation of a market where this cost is cleared. Displacement costs or externalities are difficult to establish. The problem is to create a mechanism by which owners of spectrum can reduce or control the amount of interference their receivers must cope with and the displacement cost they must bear.

The creation of a market can follow two paths. One choice is to setup agreements between parties about how, when, and possibly where interference can be tolerated. Decisions about the measurement of interference are left for the parties affect to decide. What can be standardized is the method of requesting rights of interfere. Such a standard could be developed through the use of control channels – frequencies in the band desired that are used to request service. Examples of such control are found in cellular telephony systems (Rappaport, 2002, p.

559-60). However, transaction costs might limit the use of this mechanism. It is also possible to use this arrangement if primaries are ready to give away spectrum for free, or if they pre-determine their interferers, creating a system like toll-way passes such as the I-Pass system (Illinois State Toll Highway Authority, 2003).

The other choice creates a market in “interference rights”. The closest analog to this is the use of permit trading to control greenhouse gas (GHG) emissions. The cost to society due to environmental externalities does not have a pre-defined monetary value attached to it. Permit trading determines this cost by limiting total emissions, translating allowed emissions into permits and creating a market in which these permits are traded. This approach creates incentives to reduce emissions to the point “where the marginal cost of reduction [of emissions] equals the marginal benefit of reduction [of emissions]” (IEA, 2001). Each emissions producer is provided with a limit on emissions for a period of time, and can sell excess permits if it produces less and buy permits if it produces more than this limit. For a detailed explanation of emissions trading, readers are referred to publications of the IEA (2001), Kennedy & Laplante (1999), and OECD (1992).

In the spectrum-as-property setup, there exists an emission (electromagnetic energy) resulting in a cost (displacement due to interference) to the environment (the spectrum band being operated in and its primaries). One can envision a system in which periodic auctions are held where “interference permits” are sold. We can use total time of interference as the good traded. Permits are then traded for different spectrum bands and interferers can decide how to use them. The more the restriction on the permit usage, the lower the expected cost per permit. Services that can withstand higher levels of interference with lower displacement costs would sell more permits. If we consider grouping of technologically similar services together – as has

been proposed in the SPTF Report (FCC, 2002c, p. 16, 22) – we could create larger regions in which acceptable levels of interference are similar, and hence, more effective auctions can be held as the number of permit sellers would be larger. The drawbacks in this system include the possible creation of disincentives for spectrum users to design and deploy better discriminating receivers, and the complexity of the transaction system. Only if the traded volume of permits is large enough could this system be viable. Additionally, the interference rights will need to be defined more clearly. It might not be enough to define it in terms of time, as it might affect certain primaries more than other due to location or temporal effects.

It is possible that these two market-based models of dealing with and managing interference can be superceded by better techniques in the future. It is crucial, though, to note that in each of the cases discussed above, users themselves, independent of regulatory influence, could define methods of interference management. This method decentralizes interference management and allows users to decide the best methods for themselves – a preferred outcome to having a regulator dictate what seems to be a potentially unfeasible and poorly designed technique of management.

VI. CONCLUSION

The interference temperature model is a reflection of the FCC's reluctance to completely decontrol spectrum management. It is proposed that agents who own and use spectrum handle interference management instead. As the models of spectrum allocation determine creation of agents, we analyzed outcomes and possibilities if agents managed interference. Following the analysis, we conclude that agents themselves would be able to effectively manage interference. Thus, the FCC should consider decontrolling interference management techniques and consider the interaction with allocation models. A user-specified interference management system is a viable option to a regulator-defined method.

There are two larger issues arising from this conclusion. The first concerns the debate being discussed. The FCC should encourage the discussion of interference management by the owners and users of spectrum. By moving away from the current and proposed centralized regulatory structures, the FCC might lay the path to developments in the use of spectrum beyond imagination. In a system where spectrum might be treated as property or as a commons, it is contradictory to expectations to impose a regulatory standard that might not even be necessary. Any debate on interference management should consider the role of the users of spectrum as the primary managers of interference.

Respectfully submitted,

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VIII. FOOTNOTES

¹ The author would like to bring attention to the fact that the FCC has defined Boltzmann's constant wrong. Kraus (1988), Lathi (1968), both influential and widely recommended books in the field of communications systems define this physical constant as having a value of $k=1.38 \times 10^{-23}$ Joules/second. (1 Joule = 1 Watt x 1 second).

² Antenna temperature is the temperature that represents the power of the electromagnetic radiations emitted from the region – also known as the equivalent temperature. It is not the physical temperature of the antenna itself, nor is it the physical temperature of the region being observed by the antenna (Kraus, 1988, p. 774-781). For example, the antenna temperature recorded by looking at another transmitting antenna may be in the millions of Kelvin, but the physical temperature of the antenna would obviously be close to ground temperature. What the FCC envisions is devices called interference thermometers would measure interference temperature in the frequency band where a user would like to transmit. The device decides if interference temperature after transmission is acceptable to the affected devices and services - that it is below the maximum allowed temperature and adjusts transmitted power or prevents transmission if interference temperature would exceed limits for that band and location (FCC, 2002c, p. 30).

³ Many comments before the FCC expressed these points (Agere Systems, 2003, p. 6; Agilent Technologies, 2003, p.6; Arch Wireless Operating Co., 2003, p. 2-4; American Radio Relay League, 2003, p. 9; AT&T Wireless Services Inc., 2003, p. 8-12; The Boeing Company, 2003, p. 8; Cellular Telecommunications & Internet Association, 2003, p. 10-13; Consumer Electronics Association, 2003, p. 7; Hendricks, 2003; IEEE 802.18, 2003, p. 7; Lockheed Martin Corp., 2003, p. 6-9; Motorola, Inc., 2003, p. 13-15; Public Safety Wireless Network, 2003, p. 8-

9; Sprint Corp., 2003, p. 15; Verizon Wireless, 2003, p. 9-16). Only one commentator was found who reported that the concept was workable and should be used in the design of new wireless communications devices in the future, proposing to undertake the development of such devices (Shared Spectrum, 2003a; Shared Spectrum, 2003b).

⁴ Information about and the FCC Part 15 Rules can be found at

<http://www.arrl.org/tis/info/part15.html#Overview> and at

http://www.fcc.gov/oet/info/rules/PART15_8-26-03.pdf

⁵ Receiver capture effect: If multiple (interfering) messages are transmitted at the same time, because of radio wave propagation effects, the signals are likely to be received with essentially different power. In such case the strongest signal is likely to capture the receiver, while only the weaker signals are lost. From

http://buffy.eecs.berkeley.edu/~linnartz/jpl_path.html